PROCEEDINGS

OF THE

ROYAL SOCIETY OF EDINBURGH.

VOL. V. | 1862–63. | No. 61.

Monday, 2d March 1863.

Principal Sir DAVID BREWSTER, Vice-President, in the Chair.

In presenting the Neill Prize, the Chairman made the following remarks:—

Before presenting the Neill Medal to Dr Greville, in conformity with the decision of the Council, it may be proper for the information of strangers, and even of many Fellows of the Society, to give a brief notice of the bequest to science which was made by the late Dr Patrick Neill.

Although Dr Neill was a member of this Society, he never took an active part in its proceedings, and I believe never communicated any paper to its Transactions. He was one of the founders of the Wernerian Society, and discharged the duties of its Secretary during the thirty years of its existence under the able presidency of Professor Jameson. The Wernerian Society was, indeed, the rival of the Royal Society of Edinburgh, and its seven volumes of Transactions contain many papers by distinguished writers which would otherwise have been communicated to this Society.

Dr Neill's first publication appeared in 1806, and was entitled "A Tour through some of the Islands of Orkney and Shetland." In 1829 he published his "Horticultural Tour in Flanders," and in

1845 his "Fruit, Flower, and Kitchen Garden," which was a republication of the article "Horticulture" in the Edinburgh Encyclopædia. Dr Neill communicated only two papers to the Wernerian Transactions, one entitled "A List of Fishes in the Forth, and Lakes and Rivers near Edinburgh," and another "On the Fossil Remains of the Beaver in Perthshire and Berwickshire."

Dr Neill died in 1851, and bequeathed to the Royal Society of Edinburgh the sum of L.500, "the interest of which was to be applied in furnishing a medal every second or third year to any distinguished Scottish Naturalist, to be adjudicated by the Council of the Society."

In fulfilling this trust, the Council wisely adopted the triennial in place of the biennial period, and the first adjudication of the prize was made to Dr Lauder Lindsay for his researches on the structure of lichens.

The second adjudication was made to Dr Robert Kaye Greville "for his contributions to Scottish Natural History, more especially in the department of Cryptogamic Botany, including his recent papers on Diatomaceæ."

Dr Greville's contributions to Natural History have been both numerous and valuable, and their merits have been recognised by the most distinguished Botanists of the age. His "Scottish Cryptogamic Flora" was published between 1823 and 1828. His "Flora Edinensis" appeared in 1828. His "Algæ Britannicæ, or, Description of Marine and other Inarticulated Plants in Britain belonging to the order Algæ," was published in 1830, and he has inserted in the "Microscopical Journal" no fewer than twelve papers on the Diatomaceæ, an interesting subject which still occupies his attention.

But Dr Greville's services to science have not been limited by his writings. He has been an ardent collector of plants and other objects of natural history; and his complete herbarium of Phanerogamous and Cryptogamous plants, as well as his collection of insects, have been placed in the Museum of our University. He has also made a collection of land and fresh-water mollusca, which is the finest in Scotland.

These various contributions to natural history have been highly appreciated both in this and in foreign countries. In 1824 the

University of Glasgow conferred upon Dr Greville the degree of Doctor of Laws, and many of the Natural History Societies in Europe and America have received him among their corresponding or honorary members.

Though somewhat foreign to the present occasion, the Society will, I trust, excuse me for adding, that Dr Greville has taken an active part in those interesting questions of philanthropy, on the solution of which the happiness and security of society depend. He has felt, as I am sure most of us here feel, that there is something greater than science, and something higher and more enduring than fame; and it is no slight ground of congratulation, that some of those who have been commissioned by their Maker to study His works, and to sound the depths of His wisdom and His power, have shunned the fatal course which others have pursued, of sapping the foundations of that faith and hope which science is so able to sustain.

Dr Greville, In the name of the Council I now beg to present to you the Neill Medal, and to congratulate you on this honour, which you have so well merited.

The following Communications were read:—

1. Letter from Sir D. Brewster relative to the specimens of Topaz with Pressure Cavities presented by him to the Museum of the Society.

Dear Professor Balfour,—In vol. xvi. of the "Transactions of the Royal Society of Edinburgh," I have described and given drawings of the pressure cavities which I discovered in topaz; and in vol. xxiii., just published, I have pointed out the geological relations of these cavities.

As the specimens of topaz containing them are so rare that I have found only *five* out of many hundreds which I have examined;—as the existence of such cavities with a polarising structure around them, proving that the topaz was in a soft or plastic state, will hardly be admitted by those who believe that the topaz was formed by aqueous deposition;—and as it is quite possible that other specimens containing such very minute cavities may never be found,

even when diligently searched for, I think it right to present to the Society for preservation the *five* topazes in which the cavities were found.—I am, ever most truly yours.

(Signed) D. Brewster.

Allerly, *Feb.* 7, 1863.

2. On the Polarization of Rough Surfaces, and of Substances that reflect White or Coloured Light from their Interior. By Sir David Brewster, K.H., F.R.S.

3. On a Clay Deposit with Fossil Arctic Shells, recently observed in the Basin of the Forth. By the Rev. Thomas Brown, F.R.S.E.

The author having stated the circumstances which led to his discovering this bed with its fossils near the harbour at Elie, referred to a drawing of the section, and explained the position and contents of the different strata.

Specimens of the shells were exhibited, as named by Dr Otto Torrell of Lund, who had supplied important information as to their distribution. They are all, without exception, now living in the Arctic Seas. A majority of them are exclusively Arctic. Several are new to the British glacial deposits—viz., *Thracia myopsis*, *Pecten groenlandicus*, *Crenella decussata*, *C. lævigata*,* *Turritella erosa*,† and a new *Yoldia* found in Spitzbergen in 80° north latitude.‡ It was shown how strongly this evidence goes to prove the former existence of a Boreal or Arctic climate in Scotland.

The shells seem also to indicate some considerable rise in the level of the land. They are deep-water species—some of them very markedly so. Four distinct series of facts appear to show that they have not been washed up and transported, but are lying in the clay-bed where they originally lived. As the deposit is now rather above high-water mark, the fair inference would seem to be

* "Most probably, but much injured."

† "Almost certainly this species, yet cannot be positively asserted."

‡ The other species are—*Saxicava rugosa*, large form, *Tellina proxima*, *Astarte compressa*, *Leda truncata*, *L. pygmæa*, *Natica groenlandica*, large form. Fragments also occur which seem to belong to *Cyprina Islandica* and *Mya truncata*.

that the whole sea-bed of the Firth must have been considerably raised.

Reference was made to the discovery of the glacial beds of the Clyde by Mr Smith of Jordanhill. They had been looked for on the Forth, but without success. Dr Fleming struck the first trace of them at Tyrie, but it was faint, there being only two or three specimens of the shells, and these he was led to think not indigenous. In the Elie clay the same two species occur rather abundantly, along with others, all evidently in the clay-bed where they had lived. The group is so characteristic that there need be no question now as to the occurrence of the true old glacial beds with Arctic shells in the basin of the Forth.

Various reasons were stated for holding that this bed is very closely connected with the boulder clay, being not improbably a sea-formation contemporaneous with some portion of that deposit.

It was shown, that the facts brought to light in this section give us some glimpse into the circumstances under which the period of Arctic cold passed away.

The submerged forests of the Fifeshire coast were referred to in connection with the information which this section seems to furnish as to the somewhat obscure question of their true stratigraphical position.

4. On the Remarkable Occurrence of Graphite in Siberia. By Thomas C. Archer, Esq.

The author in this paper gives the localities of three large mines of this mineral. The first situated in the Semipalatinsk district, Western Siberia, between 47° and 50° N. Lat., and in 80° E. Long. from Greenwich, on the Kirghesian Steppe. The locality of the mine is remarkably barren, and upon digging down a few feet, the graphite is found lying in a continuous stratum which has been ascertained to extend over a space of 2100 acres. This immense deposit belongs to Messrs Samsonof and Mamontof of Sernopol, and is worked for commercial purposes.

The second deposit is of a similar character as to its stratification; but instead of being covered with a bed of peaty soil, as in the case of the former, it has overlying it, a stratum of spathose iron ore of

a very peculiar texture, being close grained and black, and breaking with a remarkable conchoidal fracture. This mine is situated in Eastern Siberia, on the Lower Tunguska, about 240 miles from its confluence with the Ye-nee-sey, its geographical position being between 50° and 65° N. Lat., and in 102° E. Long.

The bank of the river for 1960 feet is formed entirely by a section of the graphite stratum, varying from 35 inches to 5 feet in thickness, and above it, often receding several feet, the stratum of spathose-iron ore, also about 5 feet in thickness. These beds of graphite and iron ore being washed by the river floods, are quite bare for from 30 to 105 feet inland, where a bank begins to rise, formed by the detritus of a mountain side; one of the chain of Alexyef, which itself is placed about 1800 feet from the shore. This mountain is composed of gneiss, and it has not been ascertained whether either of the strata above mentioned pass into the mountain, but they have been traced nearly to the base by borings, and have been found to extend, without varying very much in thickness, over a space of about 1960 square feet, computed to contain 12,000,000 cubic feet of graphite.

The author believes that no similar beds or strata of graphite have ever been discovered, this mineral usually being in imbedded masses, rarely very large, or in large nodules in *pockets* formed in trap and other igneous rocks.

The third mine described—namely, that of M. Alibert—is of this character. It is also in Eastern Siberia, at the foot of Mount Balagool, 98° 30″ E. Long., by 52° 20″ N. Lat., 200 miles west from Irkutsk. Mount Balagool is composed chiefly of sienite, and it is by laborious operations that the graphite is raised to the surface. The mines are worked by the half-wild Buriates of the district; but the quality of the graphite is so remarkably fine that it amply repays the labour, L.1200 worth having being raised in the first four months.

The author called attention to these mines, because, from their vastness, as compared with other graphite deposits, they assume a geological importance, and are rendered peculiarly interesting by the facts lately stated by Dr Pauli respecting the development of plumbago in the process of manufacturing caustic soda on a large scale.

The following gentleman was admitted a Fellow of the Society:—

Rev. Robert Nisbet, D.D.

The following Donations to the Library were announced:—

Proceedings of the British Meteorological Society. Vol. I. Nos. 1–4. 8vo.—*From the Society.*

List of Members of the British Meteorological Society. 1862. August.—*From the same.*

Catalogue of Books in the Library of the British Meteorological Society. August, 1862. 8vo.—*From the same.*

Eleventh Report of the Council of the British Meteorological Society for the year 1861. 8vo.—*From the same.*

The American Journal of Science and Arts. January, 1863. 8vo.—*From the Conductors.*

Proceedings of the American Philosophical Society. Vol. IX. No. 68. 8vo.—*From the Society.*

The Journal of Agriculture. March 1863. 8vo.—*From the Highland and Agricultural Society.*

Quarterly Return of the Births, Deaths, and Marriages registered in the Divisions, Counties, and Districts of Scotland. No. XXXII. 8vo.—*From the Registrar-General.*

Supplement to the above. 8vo.—*From the same.*

Denkschriften der kaiserlichen Akademie der Wissenschaften. Philosophisch-historische Classe. Zwölfter Band. 4to.—*From the Academy.*

Sitzungsberichte der kaiserlichen Akademie der Wissenschaften. XXXIX Band. ii, iii, iv, u. v, Heft; u. XI Band. i. u. ii, Heft. (Philosophisch-historische Classe.) 8vo.—*From the same.*

Sitzungsberichte der kaiserlichen Akademie der Wissenschaften Mathematisch-naturwissenschaftliche Classe XLV Band, iii, iv, u. v, Heft (Erste Abtheilung), u. v, Heft (Zweite Abtheilung); u. XLVI Band. i, u. ii, Heft (Zweite Abtheilung). 8vo.—*From the same.*

The Plants Indigenous to the Colony of Victoria, described by

Ferdinand Mueller, Ph.D., M.D., &c. Vol. I. Thalamifloræ. 4to.—*From the Author.*

Maps of the Ordnance Survey of Scotland. With Catalogue.—*From Colonel Sir Henry James.*

Monday, 16th March 1863.

Dr CHRISTISON, Vice-President, in the Chair.

The following Communications were read:—

1. On the Polarization of the Atmosphere. By Sir David Brewster, K.H., F.R.S.

2. Concluding Note on the Star Observations at Elchies. By Professor C. Piazzi Smyth.

In the former paper, read in December 1862, the author had detailed the points of interest that had been found in discussing the angles of position, distances, and magnitudes of certain double stars which he observed at Elchies with Mr Grant's fine telescope in last September; and he now treated similarly the observations of the *colours* of the stars then and there observed. The chief point to notice being, that in certain cases the colours undergo periodical variations; with the star "95 Herculis" in twelve years, almost exactly within the tenth part of a year, if older records can be trusted to implicitly; and such periodical change the author considered a new feature in this branch of astronomy, and one of a most important and hopeful character for observers to follow up in future.

The paper concluded with a well-merited tribute of praise to Mr Grant of Elchies, for his services to science, in planning, causing to be made, and then erecting, his large equatorial telescope; and with sincere condolence for his subsequent long illness, "which alone is the cause that he himself has not been the first to contribute to a learned Society observations, and perhaps discoveries, made by himself with the said telescope."

3. On a new fossil *Ophiuridan*, from Post-pliocene strata of the valley of the Forth. By Professor Allman.

I am indebted to one of our University students, Mr Peter Lawson, for a specimen of a star-fish, which he informed me had been found, along with many others, in a deposit of brick-clay near Dunbar. The interest of this fact was a sufficient inducement to cause me at once to visit the locality where the star-fish was obtained, and where, by the kindness of Mr France, the proprietor of the brick-works, I succeeded in obtaining good specimens of the fossil.

Notwithstanding some very marked characters, which might possibly be regarded as possessing higher than specific value, I prefer referring the star-fish of the Dunbar brick-clay to Müller and Troschel's genus *Ophiolepis*, rather than encumbering the existing nomenclature with a new and doubtful generic name. The species, which is very distinct from every other described member of the genus, may be defined by the following diagnosis :—

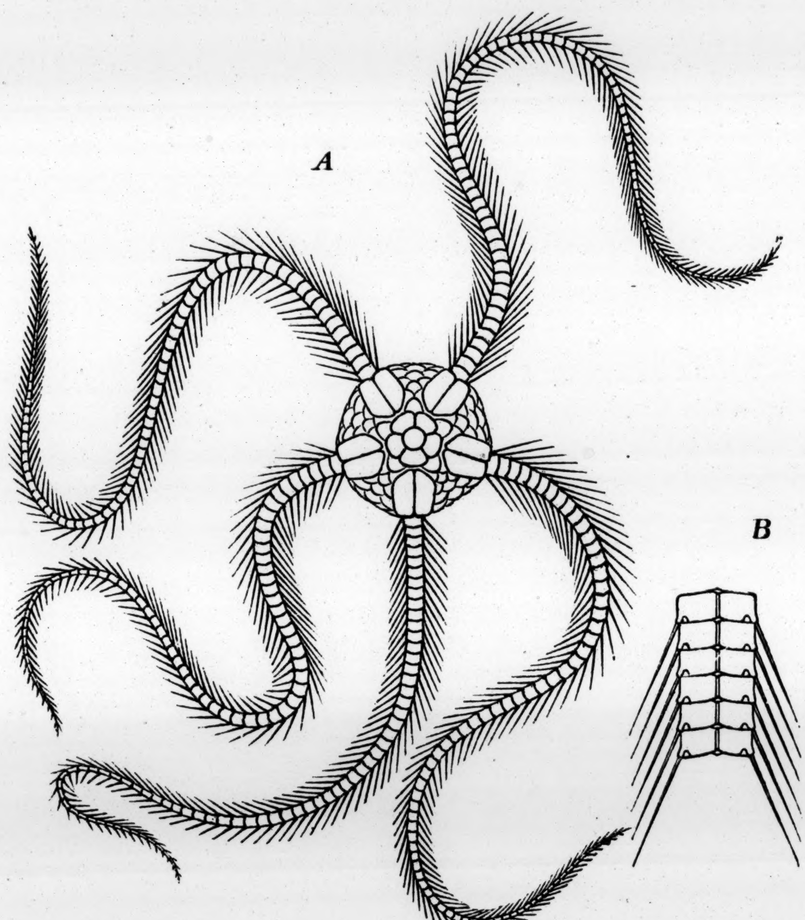
Ophiolepis gracilis (mihi), nov. spec.

Upper surface of the disc covered with imbricated plates, a single circular plate occupying the centre, and with the radial shields large, and having their opposed edges in contact for their entire length. Dorsal shields of the arms about twice as broad as long near the disc, and thence with their breadth gradually decreasing in proportion to their length, until towards the distal extremity of the arm they become longer than broad; they cover the whole dorsal surface of the arm, and have their adoral and aboral margins transverse and parallel. Ventral shields of the arms very minute, and allowing the lateral shields of one side to meet those of the opposite side in the inferior median line of the arm. Aboral edge of each lateral shield with a notch for the exit of a cirrus. Spines about once and a-half as long as the breadth of the arms. Arms about five times as long as the diameter of the disc, and gradually tapering to a fine point.

The size of the largest specimens obtained is about four inches from tip to tip of the arms.

One of the most remarkable features in the present species is the rudimental condition of the ventral shields of the arms; these shields being much smaller than in *Ophiolepis ciliata* (Mül. and

Fossil in brick-clay of the Post-pliocene age, near Dunbar, Scotland.



Ophiolepis gracilis—(A) viewed from the dorsal side, slightly enlarged; (B) ventral wall of one of the arms still more enlarged viewed from within; showing the lateral shields slightly separated from one another along the mesial line, where the minute ventral shields are introduced between their angles. The apertures for the exit of the ambulacral cirri are seen near the outer edges of the lateral shields.

Trosch.), where they are exceptionally small among the *Ophiuridæ*, and where the lateral shields bear only short papilliform spines instead of the long, highly-developed spines of *O. gracilis*. It was

only after having sought in vain for the ventral shields in some dozens of specimens that I succeeded in detecting them in a single instance. In this case they appeared in a view of the internal surface of the ventral wall (fig. B) as very minute rhombic plates lying along the mesial line, where they were interposed between the angles of the lateral shields. It is quite possible that the ventral plates are more fully displayed upon the outer surface of the wall, but in no case did I find this surface sufficiently exposed to enable me to obtain a view of them; while the inner surface, on the contrary, was frequently well exposed by the disappearance in the fossil of the dorsal shields, and of the series of vertebra-like ossicles, which, in the living *Ophiuridæ* occupies the axis of the arms. In most of the specimens sufficiently well preserved to afford a view of the ventral walls of the arms, the lateral shields were seen to be slightly separated from one another along the ventral suture, leaving here a distinct but narrow fissure, which was not interrupted even by the intervention of the minute ventral plates, which had in almost every case disappeared. In some instances, however, the lateral shields escaped displacement, and the two series were then in contact with one another along the line of suture. The notch for the exit of the cirri or tentacular ambulacra, situated on the aboral edge of every lateral plate, is very distinct, and is completed into an entire aperture by the adoral edge of the plate next in succession. The spines along the sides of the arms are long and slender; in no case, however, could I satisfy myself that more than a single spine was borne by each lateral shield; but the condition of the specimens does not justify our thus limiting the number of those spines. Neither was I able to discover in the specimens any evidence of scales over the apertures for the cirri.

The deposit in which *Ophiolepis gracilis* occurs is a fine dense tenacious blue clay of Post-pliocene age. It is situated upon the shore of the Firth of Forth, about two miles to the west of Dunbar, and is largely worked for the manufacture of bricks. It lies low; and were it not for an artificial embankment, would be flooded at high tide.

In this deposit, at about five feet from the surface, is a horizontal bed, where the star-fishes are found. They occur in great numbers upon the surface of the bed, which is occasionally separated from

the bed above it by a thin parting of fine sand. They are remarkable for their unmutilated condition, lying there with their slender arms, even to the extreme points, in the position which they must have naturally held during life, thus showing an entire absence of that spontaneous dismemberment which is so characteristic of the *Ophiuridæ* when dying under any prolonged irritation, and indicating some sudden cause of deprivation of life, such as we may suppose to result from an irruption of fresh water into the part of the sea inhabited by them.

None of the specimens I obtained, however, were sufficiently well preserved to enable me to make out all their characters as completely as I could have wished, the nature of the clay in which they were imbedded being apparently not suited to the preservation of the more delicate structures. The oral surface of the disc, especially, was in no case retained so perfectly as to allow of the mouth or the disposition of the plates of this part of the animal being observed. It was only in some instances that traces of the spines were visible, and then almost the only indications left were their impressions in the surrounding clay.

It is a curious and interesting fact, that not only did all the specimens found belong to a single species, but that not a vestige of a shell, or of any other organism, could be detected in any part of the clay which I had an opportunity of examining.

The following gentlemen were admitted Fellows of the Society:—

The Hon. Lord Ormidale.

Joseph D. Everett, M.A., Professor of Mathematics and Natural Philosophy, King's College, Windsor, Nova Scotia.

The following donations to the Library were announced:—

Almanaque Náutico para 1864, calculado de órden de S. M. en el Observatorio de marina de la ciudad de San Fernando. Cadiz. 1862. 8vo.—*From the Director of the Observatory.*

Proceedings of the Linnean Society. Vol. VII., No. 25. 8vo. —*From the Society.*

The Canadian Journal of Industry, Science, and Art. February, 1863. 8vo.—*From the Canadian Institute.*

Proceedings of the Horticultural Society. March 1863. 8vo.—*From the Society.*

Transactions of the Historic Society of Lancashire and Cheshire. New Series. Vol. II. 8vo.—*From the Society.*

Proceedings of the Royal Institution. Vol. I. 8vo.—*From the Institution.*

Monthly Notices of the Royal Astronomical Society. Vol. XXIII. No. 4. 8vo.—*From the Society.*

Abstracts of the Proceedings of the Geological Society of London. No. 91. 8vo.—*From the Society.*

The Journal of the Chemical Society. Nos. II. and III. 8vo.—*From the Society.*

Monthly Return of the Births, Deaths, and Marriages registered in the Eight Principal Towns of Scotland. February, 1863. 8vo.—*From the Registrar-General.*

Journal of the Statistical Society of London. March 1863. 8vo. —*From the Society.*

Pilote Francaise.—*From the Depôt de la Marine.*

Monday, 6th April, 1863.

Professor KELLAND, Vice-President, in the Chair.

Mr J. D. Marwick presented, through Professor Smyth, specimens of lead from the roof of the lower storey of Nelson's Monument, on the Calton Hill, injured by lightning.

The following Communications were read :—

1. Accompanying Note to Portions of Lead from the Roof of the Lower Storey of Nelson's Monument, injured by Lightning on the evening of 4th February 1863. By Professor C. Piazzi Smyth.

The portions of sheet-lead above mentioned had attracted my attention on the days following the 4th of February, when engaged in repairing some damage which had then occurred to the electric wires connecting the Nelson Monument and the Observatory; and finding

that plumbers (employed by the Town-Council) were removing the old lead and substituting new in its place, and being also encouraged by Professor P. G. Tait, who with me visited the spot, to believe that the markings which had been discovered were electrically of unusual interest, I lost no time in applying to Mr J. D. Marwick, town-clerk, for those portions of the leaden covering which contained the marks in question, with the view of presenting them to the Royal Society.

Mr Marwick was as obliging as prompt in responding to such a request, and sent me the required specimens next day, accompanied by the enclosed memorandum written by Mr H., assistant to Mr Cousin, city-architect.

10*th February* 1863.

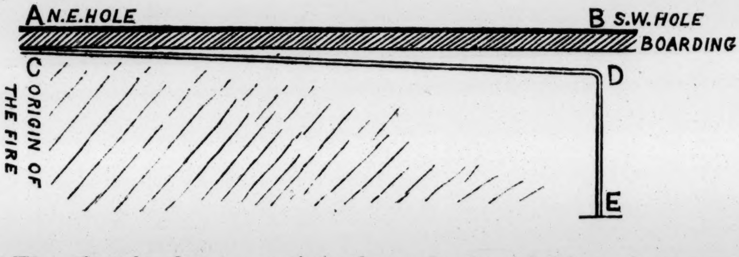
"The accompanying pieces of lead were taken from the north-west side of the lead platform on the roof of the lower part of Nelson's Monument.

"The distance between the holes was about nine feet six inches.

"Both holes were immediately over a block-tin gas-pipe, which is here carried under the lead and boarding of the platform, and which was found melted the whole length between the two holes, and a foot beyond the north-east hole.

"These holes in the lead were evidently *directly* caused by the burning gas from the pipes underneath.

Fig. 1.



"The sketch shows section through the platform between the two holes A and B. CD shows the gas-pipe under and between them.

"From this sketch we might naturally expect a hole melted in the lead at A, the pipe being here at its highest level immediately under the boarding, only one inch from the lead.

"The pipe between C and D would very quickly be melted by

the burning gas, as it lies horizontally and can be more easily acted on by a flame issuing from it.

"At D the pipe dips vertically about eighteen inches.

"It is evident that the *vertical* length of pipe DE would not be readily melted by the strong flame burning at D.

"The boarding and lead at B, immediately over D, would therefore be exposed to the flame of the gas for a much longer time than any part between A and B. And here we might expect what we find, a large piece of the boarding burnt, and the larger of the two holes in the accompanying pieces of lead.

"How the gas was at first ignited remains to be shown.

"H."

The above memorandum gives an excellent matter-of-fact description of what chiefly remained to be seen at the time when it was written, but it does not mention what had much struck me several days previously, when I first caught sight of the small and neat oblong hole in the roof at A; and, on subsequently pulling up the leads, which at that time had not been disturbed at that place since the storm, I found the under surface of the metal strangely burred and scored around the aperture, and also perceived small globules of melted lead, driven away apparently by some radiating force from the hole, until caught and jammed between the remaining uninjured lead and its wooden surface of support.* Neither does the memorandum account for the first igniting of the gas, but expressly says, that what may have caused that "remains to be shown."

This is in truth the most important part of the whole affair, and which I will now endeavour to describe.

The evening of the 4th of February 1863 ushered in one of the most violent storms of thunder and lightning that has been experienced in Edinburgh, and perhaps in most parts of Scotland, for many years, and its violence was all the more remarkable, inasmuch as the month of February is near the minimum of the year for

* These globules had very imperfect adhesion, and had mostly dropped off when the plate was presented to the Royal Society; but some few of the more distant ones still remained, and all the others had left marks, usually of a yellowish colour, showing their former positions, sizes, and shapes.

electrical manifestations in the shape of thunder-storms. This point, not yet generally acknowledged, is indicated pretty certainly by the following numbers, extracted from the Registrar-General's printed Reports for Scotland; they are, in fact, the deductions prepared for that officer at the Royal Observatory, Edinburgh, from the schedules of fifty-five observers of the Meteorological Society of Scotland, and give, for the means of three years, as follows:—

	Number of Stations at which Lightning was seen.	Mean Number of Times at each Station.
January, . . .	34	4
February, . . .	11	2
March, ...	42	3
April, ...	24	4
May, ...	86	5
June, ...	85	7
July, ...	91	7
August, . . .	54	3
September, . .	31	3
October, . . .	50	8
November, . .	30	4
December, . .	37	4

The storm, then, was anomalous in its season of occurrence, and in its violence; also, as it would appear from the newspaper accounts, by the regularity and broad spread of its passage over the country from west to east, occurring nearly an hour earlier at Greenock than at Aberdeen or Edinburgh. In Glasgow and its neighbourhood several buildings were struck, a tall chimney and a church entirely ruined; a lodging-house of operatives injured in every floor; and a large number of the telegraph instruments of the Private Telegraph Company thrown out of order, and one clerk rendered senseless.

This storm began in Edinburgh about 7^h P.M., and lasted nearly an hour; it came with very strong west wind, and accompaniments of rain and hail; and it was described to me by Mr Wallace, who was on the Calton Hill at the time, as being most remarkable for the slanting, almost horizontal, direction of the lightning, as well as

its greenish-blue colour. The thunder was at the same time deafeningly loud, and on one occasion apparently coincident with the flash; shaking the house he was in (the old Observatory Tower), and giving the idea that either that building, or the Royal Observatory, must have been struck. Going out immediately to see what might have happened, he met the servant at the door, who spoke of the flash of lightning having entered the lowest room of that tower, "gone half way across the floor," and left an overpowering smell of "brimstone" behind; and also called his attention to Nelson's Monument, about 200 yards east-south-east of them, being apparently on fire, because sparks were issuing from the roof of one of the low rooms at its foot, on the western side.

Now, at the winter period of the year, it seems that the tenant there (Mrs ———) finding the above monumental building very cold, prefers to live in a wooden house close by, and on the evening of the 4th of February she was in that house ill and in bed; but when the particular flash occurred which had been so much noticed by Mr Wallace and the Observatory servant, it seemed close to her also, filled her house with the brimstone odour, and so firmly impressed her with the belief that the Monument had been struck, that she sent out her servant "to see if the time-ball was still at the top of the building;" believing that if mischief had occurred anywhere from lightning, it would be near the summit of the structure. The answer, however, brought back was, that the time-ball was quite safe, but that sparks were coming out of the roof of the low west room. The policeman of the hill was likewise on the ground almost immediately after the flash, and testified both to the then sudden appearance of sparks issuing from the roof of the uninhabited room, and its accompaniment,by the traditional sulphurous smell in the air of strong lightning, or "ozone."

The door of the Monument was then speedily opened, access to the roof obtained, and the new-lit fire, caused by the burning of gas and wooden rafters, speedily extinguished. In this manner the gas, no doubt, after it was set on fire, did much mischief to both leaden roof and wooden rafters, especially at the place on the sketch marked B, which contains big and rather confused holes; but if any one still asks what first set the gas on fire, I think there is equally little doubt that we may answer "it was that particular

slanting flash of local and ozone-producing lightning which excited the residents on the hill so much at the time."

We may probably also assume that the lightning struck at the point A. I had already been directed to that point from the

Fig. 2.

The hole at "A," as it appears on the under surface of the lead; carefully drawn full size by Mr J. M. Corner, wood-engraver.

similarity of the hole there, to a lightning hole in sand, but could not imagine why the fluid should have pierced a hole through a good conductor, viz., a sheet of lead. On mentioning this difficulty to Professor Tait, he remarked, "that if the hole was due to the immediate action of the spark, I might be quite sure that there was a conductor below, which the lightning was trying to get at and pass off by," and *after* that opinion had been so expressed, the lead was lifted at the place (it had previously only been raised at B), and the gas-pipe was found precisely there at its closest point of approach anywhere to the roof, as may be seen clearly repre-

sented in the assistant architect's subsequent and independent drawing.*

However anomalous, therefore, the case may appear at first, some theoretical principles are remarkably borne out by it; and that the foot of the building should have been struck, and not the top, seems to follow from the low, level and almost horizontal direction in which the lightning was sensibly observed to come, and with the wind and rain,—causing thereby the windward foot of the tall building to become for that occasion the shortest passage for the fluid to reach the ground by.

In such a case, though, it may be suggested, that the long horizontal wire extending through a length of 4000 feet between the Nelson Monument and the castle for the service of the time-gun, should have been most abundantly charged by induction. That is true; and there is little doubt but that the said wire was copiously filled, and might have produced dangerous effects, had it not been furnished at either end with large copper plates in close proximity to many pronged conductors ending in wet earth, which led away innocuously the greater part of the charge. Enough however still remained to do some singular damage to the electrically controlled clocks at either end of the line. Thus, the members of one of the bundles of permanent magnets, near the pendulum-bob of the castle clock, had their poles changed and their new attraction made rather stronger than their old; the members of a similar bundle in the Observatory window-clock had their poles partially changed; and in the interior of the Normal Mean Time clock one of the gold contact points was partially fused, and spattered on its steel spring, which was blued at that part as though by heat.

The gold contact point thus treated, it will be understood, was in direct metallic connection at the instant with the long open-air wire; and the magnets that were altered were in indirect connec-

* Professor Tait has also remarked, and it seems well worthy to be noted as a memorandum for any future occasion, that it would have been advisable to have preserved the boarding at "A," as well as the lead; for the manner of action and of piercing through wood by lightning is very different to the burning action of flame; and thick wooden planking *was* everywhere interposed between the gas-pipe and the leaden roof.

tion, or rather, in inductive position, for they were surrounded at the time by the wire coil of the pendulum-bob, whose composing wire is a connected continuation of the long open-air wire.

To this it only remains to add, that these lightning-made magnets at the Castle clock, when duly replaced in the bundle suitably with their new poles, have given the most steady and satisfactory results in working the control of the clock ever since.

2. Note on the Anatomical Type in the Funis Umbilicalis and Placenta. By Professor Simpson.

3. On Earth-Currents during Magnetic Calms, and their Connection with Magnetic Changes. By Balfour Stewart, Esq., M.A., F.R.S. Communicated by Professor Tait.

In two previous communications made by the author to the Royal Society of London, it had been endeavoured to show that earth-currents and auroræ, which occur simultaneously with magnetic storms, are secondary currents due to the small but abrupt changes in the magnetism of the earth which such storms denote. Earth-currents also occur during periods of magnetic calm, but they can then be rendered visible only by means of a delicate galvanometer.

Such has been constructed by Mr C. V. Walker, who has by its means registered those earth-currents which occurred during the three last months of 1851, a period of magnetic calm.

The object of the present communication is to discuss those observations of Mr Walker in connection with the simultaneous changes which took place in the values of the declination and the horizontal force component of the earth's magnetism, these changes being furnished by means of continuously acting magnetographs at Kew Observatory. By this method Mr Walker's observations were divided into three classes,—

1*st class*. Observations during moments of magnetic calm.
2*d* „ Observations during minor magnetic disturbances.
3*d* „ Observations during greater magnetic disturbances.

In the first of these classes a law of hours was manifestly observed; the values of the earth-currents for the hours of the night being extremely small. But in the second, and especially in the third class, the law of hours was observed to fail; and in the latter of these classes the peculiar action of disturbances was very manifest, the tendency of such disturbances being to create very strong earth-currents at the moment of their occurrence; and it is noticeable that these earth-currents were as often positive as negative.

It was remarked by the author, that the very great strength of those earth-currents, which take place at the moments of disturbance, is in favour of the theory of induction, since the peculiarity of a disturbance is not so much *a very great* as *a very rapid and abrupt* departure of the magnet from the normal position; and since, on the theory of induction, the corresponding earth-current will be due to abruptness of magnetic change, we thus obtain an explanation why the currents which accompany disturbances are so very powerful, and also why these are as often positive as negative.

With regard to the first class of earth-current observations, or those which occurred during magnetic calm, the author believed the daily range indicated by these observations to be the induction effect of the daily magnetic change, on which hypothesis the small value of the currents for the night hours might be accounted for by the corresponding fact that during these hours the magnetic change is exceedingly small.

4. Note on a Pictish Inscription in the Churchyard of St Vigeans. By Professor Simpson.

Dr Simpson considered the inscription to be "Drosten, Son of Voret, of the family of Fergus."

5. On some Kinematical and Dynamical Theorems. By Professor W. Thomson. (Abstract by Professor Tait.)

In the course of investigations which the author had been led to make in connection with a Treatise on Natural Philosophy which he and Professor Tait are about to publish, he met with some remarkable theorems, which appear to be new and of considerable

importance. As the details of the investigations will soon be published, a very brief sketch only is given here.

I. *Twist* of a wire. If a straight wire, of uniform section, have a side line of reference traced on its surface parallel to its axis; and if a perpendicular to this line from any point of the axis be called a *transverse*, the amount of torsion or twist of the wire, when bent into any form, may be determined by the following construction:—

Parallel to the tangent to the axis of the wire, at a point moving along it, let a radius of an unit sphere be drawn, cutting the spherical surface in a curve. From points of this curve draw parallels to the transverses at the corresponding points of the bar. The excess of the change of direction from one point to the other in the curve, above the increase of its inclination to the transverse, is equal to the twist in the corresponding part of the wire.

From this some very curious consequences follow, of which one is as follows:—If a wire be bent along any curve on a spherical surface, so that a side line of reference lies all along in contact with the sphere, it acquires *no twist;* so that when an apple (supposed spherical) is peeled, there is no twist in the peel.

Again, if an infinitely narrow ribband be laid on a surface along a geodetic line, its twist is at every point equal to the tortuosity of its axis.

II. Given any material system at rest, and subjected to an impulse of any given magnitude and in any specified direction, it will move off so as to take the greatest amount of kinetic energy which the specified impulse can give it.

Cor. If a set of material points be struck independently by impulses, each given in amount, more kinetic energy is generated if the points are perfectly free to move each independently of all the others than if they are connected in any way.

III. Given any material system at rest. Let any parts of it be set in motion suddenly with given velocities, the other parts being influenced only by their connections with those which are set in motion, the whole system will move so as to have less

kinetic energy than belongs to any other motion fulfilling the given velocity conditions.

6. Note on a Quaternion Transformation. By Prof. Tait.

The following paper gives an idea of the nature of the physical applications of quaternions to which I referred in a previous note (*Proceedings*, April 1862), but which other avocations have, as yet, prevented me from developing into a form and bulk suitable for publication in the Society's Transactions. The equations I now give form the *basis* of the investigations in question, which I hope to present to the Society in detail on some future occasion.

I. If the vector of any point be denoted by

$$\rho = ix + jy + kz, \quad \ldots\ldots (1)$$

there are many interesting and important transformations depending upon the effects of the quaternion operator

$$\triangleleft = i\frac{d}{dx} + j\frac{d}{dy} + k\frac{d}{dz} \quad \ldots\ldots (2)$$

upon various functions of ρ. When the function of ρ is a scalar, the effect of $\triangleleft$ is to give the vector of most rapid increase. Its effect on a vector function is indicated briefly in my former note.

II. I shall commence with one or two very simple examples, which are not only interesting, but, as we shall see, very useful in subsequent transformations.

$$\triangleleft\rho = \left(i\frac{d}{dx} + \&c.\right)\left(ix + \&c.\right) = -3 \quad \ldots\ldots (3)$$

$$\triangleleft T\rho = \left(i\frac{d}{dx} + \&c.\right)\left(x^2 + y^2 + z^2\right)^{\frac{1}{2}} = \frac{ix + jy + kz}{(x^2 + y^2 + z^2)^{\frac{1}{2}}} = \frac{\rho}{T\rho} = U\rho \ldots\ldots (4)$$

$$\triangleleft (T\rho)^n = n(T\rho)^{n-1} \triangleleft T\rho = n(T\rho)^{n-2}\rho \quad \ldots\ldots (5)$$

and, of course,
$$\triangleleft \frac{1}{(T\rho)^n} = -\frac{n\rho}{(T\rho)^{n+2}} \quad \ldots\ldots (5)'$$

whence,
$$\triangleleft \frac{1}{T\rho} = -\frac{\rho}{T\rho^3} = -\frac{U\rho}{T\rho^2} \quad \ldots\ldots (6)$$

and, of course, $$\triangleleft^2 \frac{1}{T\rho} = -\triangleleft \frac{U\rho}{T\rho^2} = 0 \quad \ldots\ldots (6)'$$

Also, $$\triangleleft \rho = -3 = T\rho \triangleleft U\rho + \triangleleft T\rho \,.\, U\rho = T\rho \triangleleft U\rho - 1,$$

$$\therefore \triangleleft U\rho = -\frac{2}{T\rho} \quad \ldots\ldots (7)$$

III. By the help of the above results, of which (6) is especially useful (though obvious on other grounds), and (4) and (7) very remarkable, we may easily find the effect of $\triangleleft$ upon more complex functions.

Thus, $$\triangleleft S\alpha\rho = -\triangleleft (\alpha x + \&c.) = -\alpha \quad \ldots\ldots (8)$$

$$\triangleleft V\alpha\rho = -\triangleleft V\rho\alpha = -\triangleleft (\rho\alpha - S\alpha\rho) = 3\alpha - \alpha = 2\alpha \quad \ldots\ldots (9)$$

Hence $$\triangleleft \frac{V\alpha\rho}{T\rho^3} = \frac{2\alpha}{T\rho^3} - \frac{3\rho V\alpha\rho}{T\rho^5} = -\frac{2\alpha\rho^2 + 3\rho V\alpha\rho}{T\rho^5} = \frac{\alpha\rho^2 - 3\rho S\alpha\rho}{T\rho^5} \ldots\ldots (10)$$

Hence $$S\,.\,\delta\rho \triangleleft \frac{V\alpha\rho}{T\rho^3} = \frac{\rho^2 S\alpha\delta\rho - 3S\alpha\rho S\rho\delta\rho}{T\rho^5} = -\frac{S\alpha\delta\rho}{T\rho^3} - \frac{3S\alpha\rho S\rho\delta\rho}{T\rho^5}$$

$$= -\delta\frac{S\alpha\rho}{T\rho^3} \ldots\ldots (11)$$

This is the principal transformation alluded to in the title of this note. By (6) it can be put in the sometimes more convenient form

$$S\,.\,\delta\rho \triangleleft \frac{V\alpha\rho}{T\rho^3} = \delta\, S\,.\,\alpha \triangleleft \frac{1}{T\rho} \ldots\ldots (12)$$

And it is worthy of remark that, as may easily be seen, S may be put for V in the left hand member of the equation.

We have also

$$\triangleleft V\,.\,\beta\rho\gamma = \triangleleft \{\beta S\gamma\rho - \rho S\beta\gamma + \gamma S\beta\rho\} = -\gamma\beta + 3S\beta\gamma - \beta\gamma = S\beta\gamma. \quad (13)$$

Hence, if ϕ be any linear and vector function of the form

$$\phi\rho = \alpha + \Sigma V\,.\,\beta\rho\gamma + m\rho, \quad \ldots\ldots (14)$$

then $$\triangleleft \phi\rho = \Sigma S\beta\gamma - 3m = \text{scalar} \quad \ldots\ldots (14)'$$

Hence, an integral of

$$\triangleleft \sigma = \text{scalar constant, is } \sigma = \phi\rho \ldots\ldots (15)$$

If the constant value of $\triangleleft \sigma$ contain a vector part, there will be

terms of the form $V\epsilon\rho$ in the expression for σ, which will then express a distortion accompanied by rotation.

Also, a solution of $\triangleleft q = a$ (where q and a are quaternions) is $q = S\zeta\rho + V\epsilon\rho + \phi\rho$.

It may be remarked also, as of considerable importance in physical applications, that, by (8) and (9), $\triangleleft (S + \frac{1}{2}V)a\rho = 0$, but I cannot enter at present into details on this point.

IV. In this brief note, I shall not give any more of these transformations, which really present no difficulty; but I shall show the ready applicability to physical questions of one or two of those already obtained, a property of great importance, as it may now be asserted that the next grand extensions of mathematical physics will, in all likelihood, be furnished by quaternions.

Thus, if σ be the vector-displacement of that point of a homogeneous elastic solid whose vector is ρ, we have, p being the consequent pressure produced,

$$\triangleleft p + \triangleleft^2 \sigma = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (16)$$

whence $\quad S\delta\rho \triangleleft^2 \sigma = -S\delta\rho \triangleleft p = \delta p$, a complete differential.... $(16)^1$

Also, generally, $\quad p = kS \triangleleft \sigma,$

and if the solid be incompressible

$$S \triangleleft \sigma = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (17)$$

Thomson has shown (*Camb. & Dub. Math. Journal*, ii. p. 62), that the forces produced by given distributions of matter, electricity, magnetism, or galvanic currents, can be represented at every point by displacements of such a solid producible by external forces. It may be useful to give his analysis, with some additions, in a quaternion form, to show the insight gained by the simplicity of the present method.

Thus, if $S\sigma\delta\rho = \delta \frac{1}{T\rho}$, we may write each equal to $-S\delta\rho \triangleleft \frac{1}{T\rho}$. This gives

$$\sigma = -\triangleleft \frac{1}{T\rho}$$

the vector-force exerted by one particle of matter or free electricity on another. This value of σ evidently satisfies $(16)^1$ and (17).

Again, if

$$S.\delta\rho \lhd \sigma = \delta \frac{S\alpha\rho}{T\rho^3}, \text{ either is equal to}$$

$$-S.\delta\rho \lhd \frac{V\alpha\rho}{T\rho^3} \text{ by (11).}$$

Here a particular case is

$$\sigma = -\frac{V\alpha\rho}{T\rho^3},$$ which (*Quarterly Math. Journal*, vol. iii. p. 338) is the vector-force exerted by an element α of a current upon a particle of magnetism at ρ.

Also, by (10), $\lhd \frac{V\alpha\rho}{T\rho^3} = \frac{\alpha\rho^2 - 3\rho S\alpha\rho}{T\rho^5}$, and the same paper shows that this is the vector-force exerted by a small plane current at the origin (its plane being perpendicular to α) upon a magnetic particle, or pole of a solenoid, at ρ. This expression, being a pure vector, denotes an elementary rotation caused by the distortion of the solid, and it is evident that the above value of σ satisfies the equations $(16)^1$, (17), and the distortion is therefore producible by external forces. Thus the effect of an element of a current on a magnetic particle is expressed directly by the displacement, while that of a small closed current or magnet is represented by the vector-axis of the rotation caused by the displacement.

Again, let

$$S\delta\rho \lhd^2 \sigma = \delta \frac{S\alpha\rho}{T\rho^3}.$$

It is evident that σ satisfies $(16)^1$, and that the right-hand side of the above equation may be written

$$-S.\delta\rho \lhd \frac{V\alpha\rho}{T\rho^3}.$$

Hence a particular case is

$$\lhd \sigma = -\frac{V\alpha\rho}{T\rho},$$ and this satisfies (17) also.

Hence the corresponding displacement is producible by external forces, and $\lhd \sigma$ is the rotation axis of the element at ρ, and is seen as before to represent the vector-force exerted on a particle of magnetism at ρ by an element α of a current at the origin.

It is interesting to observe that a particular value of σ in this case is

$$\sigma = -\tfrac{1}{2} \triangleleft S\alpha U\rho - \frac{\alpha}{T\rho},$$

as may easily be proved by substitution.

Again, if

$$S\delta\rho\sigma = -\delta \frac{S\alpha\rho}{T\rho^3},$$

we have evidently

$$\sigma = \triangleleft \frac{S\alpha\rho}{T\rho^3}.$$

Now, as $\frac{S\alpha\rho}{T\rho^3}$ is the potential of a small magnet α, at the origin, on a particle of free magnetism at ρ, σ is the resultant magnetic force —and represents also a possible distortion of the elastic solid by external forces, since $\triangleleft\sigma = \triangleleft^2\sigma = 0$, and thus (16)[1] and (17) are both satisfied.

The following Gentlemen were duly elected Fellows of the Society:—

The Hon. GEORGE WALDEGRAVE LESLIE.
The Hon. CHARLES BAILLIE (Lord JERVISWOODE).
JAMES SANDERSON, Esq., Surgeon-Major Madras Medical Staff.

The following Donations to the Library were announced:—

Abhandlungen herausgegeben von der Senckenbergischen naturforschenden Gesellschaft. Vierten Bandes zweite Lieferung. 4to.—*From the Society.*

Proceedings of the Geological Society of London. Nos. 95 and 96. 8vo.—*From the Society.*

Les Grandes Usines de France. 4 Parts. 8vo.

Natural History of New York. Vol. III., Part 6, on Palæontology. 2 Vols. 4to.—*From the American Government.*

Natural History of New York. Part 5, on Agriculture. 4to.—*From the same.*

Ἱπποκράτους καὶ ἄλλων ἰατρῶν παλαιῶν λείψανα. Edidit Franciscus Zacharias Ermerins. Volumen Secundum. Trajecti ad Rhenum, 1862. 4to.—*From the Dutch Government.*

Verslagen en Mededeelingen der Koninklijke Akademie van

Wetenschappen. Afdeeling Natuurkunde. Dertiende et viertiende Deel. 8vo.—*From the Academy.*

Verslagen en Mededeelingen der Koninklijke Akademie van Wetenschappen. Afdeeling Letterkunde. Zesde Deel. 8vo. —*From the same.*

Jaarboek van de Koninklijke Akademie van Wetenschappen gevistigd te Amsterdam voor 1861. 8vo.—*From the same.*

Verhandelingen der Koninklijke Akademie van Wetenschappen. Achste Deel. 4to.—*From the same.*

Journal of the Asiatic Society of Bengal. New Series. No. 113. 8vo.—*From the Secretaries.*

Report of the Royal Commission on the Operation of the Acts relating to Trawling for Herring on the Coasts of Scotland. Folio.—*From the British Government.*

The Quarterly Journal of the Geological Society. No. 73.—*From the Society.*

Transactions of the Linnean Society of London. Volume XXIV. Part 1. 4to.—*From the Society.*

Materiaux pour la Carte Geologique de la Suisse publiés par la Commission Geologique de la Société Helvetique des Sciences Naturelles aux frais de la Confederation. Première Livraison. With Chart. 4to.—*From the Society.*

Oversigt over det Kongelige danske Videnskabernes Selskabs Forhandlinger og dets Medlemmers Arbeider i Aaret 1861. 8vo.—*From the Society.*

Det Kongelige danske Videnskabernes Selskabs Skrifter femte Raekke. Naturvidenskabelig og Mathematisk Afdeeling. Femte Binds andet Hefte. 4to.—*From the Society.*

Proceedings of the Royal Society of London. Vol. XII. No. 54. 8vo.—*From the Society.*

Instructions Nautiques sur les mers de l'Inde, par James Horsburgh; traduites de l'Anglais par M. le Predour. II^e. Partié. 4to.—*From the Depôt Général de la Marine.*

Annuaire des Marées des Côtes de France pour l'an 1864 par M. Gaussin. 12mo.—*From the same.*

Publications du dépôt des Cartes et Plans de la Marine. Nos. 37–43 et 46–49. 8vo.—*From the same.*

Seventy-Fifth Annual Report of the Regents of the University of the State of New York. 8vo.—*From the University.*

Fifteenth Annual Report of the Regents of the University of the State of New York on the Condition of the State Cabinet of Natural History. 8vo.—*From the same.*

Scheikundige Verhandelingen en Onderzoekingen uitgegeven door G. J. Mulder. Derde Deel. Tweede Stuk. 8vo.—*From the Author.*

Monday, 20th April 1863.

PRINCIPAL FORBES, Vice-President, in the Chair.

The following Communications were read:—

1. On the Conservation of Energy. By Professor Tait.

(Abstract.)

(*This Lecture was given at the request of the Council.*)

What Matter or Force may be, we have not as yet the slightest idea. Matter is only known to us by the forces it exerts or resists. It is possible that there may be but one species of ultimate parts (molecules or atoms ?) of matter; but in the present state of chemical science, it is more philosophical to reason as if the ultimate parts of the various elementary bodies are distinct. However this may be, a particle of hydrogen, oxygen, sodium, or gold, exerts certain definite forces upon other particles; which forces, we have every reason to believe, will remain for ever unchanged, unless the so-called element should at some future time be decomposed.

Now, for such elementary particles, change of position (grouping) or motion (relative) is the only affection we can conceive; and we must endeavour to deduce, from the relation between forces and the motions they produce, all the phenomena of nature, except perhaps some of those exhibited in living structures.

All that is necessary for such an inquiry has been most distinctly laid down by Newton in his Axiomata, and the Scholia appended to them. A brief resumé of what Newton has there done will lead us easily and naturally to the Conservation of Energy—though stated for visible motions only, and without reference to the energies of heat, electricity, &c.

I. The motion of a body is uniform if no force act on it.

II. Change of motion is proportional to the force producing it, and takes place in the direction in which the force is exerted.

From this it follows at once, that force is measured by the *rate of change of motion* it produces; in other words, by the product of the mass, and the acceleration of its velocity.

This, combined with purely geometric ideas as to motion in the abstract, leads directly to the parallelogram of forces, and through it to the subjects of the Statics and Kinetics of a *single* particle. In order to extend our investigations to a *body*, or a system of bodies, we require the additional law,

III. To every *action* there is an equal and opposite *reaction.*

Newton shows that there are *two* ways in which this *action* may be measured, the third law being true for either. These lead to two classes of important dynamical theorems.

(*a*) Mutual pressures, tensions of rods and cords, attractions, stresses in solids or liquids, &c. &c., form one class of Actions and Reactions. We have thus, as immediate consequences, "Conservation of Momentum," and "Conservation of Areas." From this point of view, we have also the general statement, by what is commonly called "D'Alembert's Principle," of the equations of equilibrium and motion, and therefore the mathematical expression of the circumstances of any dynamical problem.

(*b*) But Newton goes farther, and points out *another* kind of action and reaction, ruled by the third law. His words are,—*si æstimetur agentis actio ex ejus vi et velocitate conjunctim, et similiter resistentis reactio æstimetur conjunctim ex ejus partium singularum velocitatibus et viribus resistendi ab earum attritione, cohæsione, pondere, et acceleratione oriundis; erunt actio et reactio . . . . . sibi invicem semper æquales.* The Actio here spoken of, the product of a force by the rate of motion of its point of application, is now known as the *rate of doing work*, or the horse-power of the prime mover. We notice amongst the various forms of the corresponding Reactio, the *rate of losing work* by the resistances, such as friction, cohesion, and weight; but we also have as a reaction, the resistance due to the *acceleration* of the various parts of the system; and in this statement (made by

Newton with reference to machines and their visible motions only, but now extended to all the phenomena of physical science) consists the "Conservation of Energy."

It would be easy to give the general investigation, but for an elementary lecture like this a very simple example will suffice,—the case of a particle moving in a straight line, and acted on by a force whose direction coincides with the line of motion.

If s be the space passed over in time t, and v the velocity, geometrical ideas lead at once to

$$v=\frac{ds}{dt} \quad\text{.............................(1)}$$

The *second* law of motion (above) gives, if F be the force, and m the mass of the particle,

$$F=m\frac{dv}{dt} \quad\text{............................(2)}$$

This is the ordinary equation of motion.

But Newton's second form of action and reaction, as connected by the *third* law, gives at once for the action of the force $F\frac{ds}{dt}$, and for the reaction of the particle due to acceleration we have $m\frac{dv}{dt}$ multiplied by v. Hence

$$F\frac{ds}{dt}=mv\frac{dv}{dt} \quad\text{...........................(3)}$$

which, as we see by (1), is merely the equation (2), with the additional factor v, or $\frac{ds}{dt}$, in each member.

While the integrated form of (2) is

$$m(v-v_0)=\int_{t_0}^{t}Fdt \quad\text{..........................(2)}^1$$

showing that the momentum, or quantity of motion is increased in any interval by the product of that interval by the average value of the force, the integral form of (3) is

$$\frac{m(v^2-v_0^2)}{2}=\int_{s_0}^{s}Fds \quad\text{.......................(3)}^1$$

expressing that the *change of vis viva* is measured by the amount of *work done by the force.* What is expended in *work* is therefore stored up as *vis viva.* (This is given generally for a single particle by Newton; *Principia*, Section VIII., Prop. XL.)

A simple case is that of a weight raised, or falling, in a vertical line. Here the work expended in raising it is so many foot pounds, each being the work employed to raise one pound a foot high. And in fact, by the ordinary formulæ for projectiles,

$$v^2 = 2gs,$$

$$\text{or } \frac{mv^2}{2} = mg.s = W.s,$$

or the *vis viva* acquired by falling through a space s, is equal to the work lost in falling, or required to restore the body to its original position. Now, the raised weight, in *virtue of its position*, has a power of doing work which it does not possess when lying on the ground; this is an example of what is called *Potential Energy*. As it loses this in falling, it gains an exact equivalent in *vis viva*, which is what is called *Kinetic Energy*. In this example we see that the *sum of the potential and kinetic energies is constant;* and the same is true in other common cases, such as the potential energy of a drawn bow and the kinetic energy of the arrow, the potential energy of compressed air in the reservoir of an air-gun and the kinetic energy of the bullet, and so on. It is true even in such a case as the potential energy of a distorted tuning-fork and the kinetic energy of the sound it produces, if we include in the latter the *vis viva* of the vibrations communicated to surrounding bodies.

It is easy to give a general proof, that if the particles of any system act each on another with forces which are in the direction of the line joining them, and dependent on the mutual distance only, in such a system the *sum of the potential and kinetic energies cannot be altered except by external forces; and therefore, if the introductory statements about matter be true, and physical phenomena such as heat, electricity, &c., be referred to motion of matter, there can be no alteration in the sum of the energies of the universe.* This is the general statement of the Conservation of Energy.

From this we at once deduce a proof of the impossibility of pro-

curing perpetual motion (*i.e.*, a machine which not only keeps up its motion but does external work) by means of any of the known forces of nature; and *vice versâ*, taking this impossibility for granted, we may show that the forces exerted by two material particles on each other must be in the direction of the line joining the two, and must depend on their distance *only*.

The first of the physical energies, distinct from visible motions, which was shown to be subject to the law of "conservation," was Heat. Bacon, Locke, and others, long ago regarded heat in a material body as a species of motion; but it was not proved to be so till a comparatively recent period, when Davy showed it conclusively by melting pieces of ice by rubbing them together in an enclosure cooled below the freezing point. Davy says, "The immediate cause of the phenomenon of Heat is motion, and the laws of its communication are the same as the laws of the communication of motion." Take, in connection with this, Newton's second form of Action and Reaction, and we have the Dynamical Theory of Heat; requiring, of course, experimental data to connect the two forms of Energy quantitatively. Rumford, by measuring the heat produced in boring cannon, and comparing it with the work expended, made a near approach to the value of the mechanical equivalent of heat—*i.e.*, to an answer to the question, "How much work is required to produce a given amount of kinetic energy in the form of heat?" Other thinkers and experimenters made more or less accurate and useful advances, but in a very small way, till Joule, about twenty years ago, made the experimental treatment of the subject his own. He showed by varied yet accordant experiments, that 772 foot pounds of mechanical energy are equivalent to the additional kinetic energy which a pound of water must acquire to raise its temperature from 60° F. to 61° F. He has extended his experimental work to others of the physical energies, and arrived at many most startling results, several of which I intend to show to-night.

The science of Thermodynamics, in which Carnot and Clapeyron made great steps before the immateriality of heat was generally recognised, has, since Joule's experiments were made, received enormous developments from Clausius, Rankine, Thomson, and others; and Helmholz, in an admirable essay (*Ueber die Erhaltung*

der Kraft) published in 1847, has extended most ingeniously the application of the principle of "conservation" through the whole range of physics, bringing out, from the principles already stated in this discourse, the explanation of electrodynamic induction, &c., besides various laws of transformation of energy, already empirically determined from experiment.

[The lecturer then performed an extensive series of experiments, involving transformations of various forms of energy, pointing out in each case the separate portions into which the original energy was broken up. It is not necessary to describe these experiments here.]

It will be seen that in all these experiments heat has been pointed out as the ultimate form taken by the original energy. This is a general law of nature,—*All energy ultimately becomes heat* Also heat, by conduction, radiation, or convection, tends ultimately to be uniformly diffused through the matter in the universe; and when uniformly diffused, cannot be made available for the production of any other form of energy, since, for the transformation of heat into any other form of energy, bodies of *different* temperatures are required. Uniformly diffused heat, then, as far as we can see at present, is the inevitable ultimate transformation of all the energy, potential or kinetic, in the universe.

[The lecturer went on to consider at some length the gravitation theory of the origin of the sun's energy, and various connected subjects, which are to a certain extent already popularised.]

2. On Fagnani's Theorem. By H. F. Talbot, LL.D.

3. On the Theory of Parallel Lines. By H. F. Talbot, LL.D.

The following Address to His Royal Highness the Prince of Wales was adopted, and ordered to be forwarded to the Duke of Argyle for presentation :—

TO HIS ROYAL HIGHNESS THE PRINCE OF WALES.

May it please your Royal Highness,—

We, the President and Fellows of the Royal Society of Edinburgh, desire humbly to approach your Royal Highness with the expression of our dutiful and heartfelt congratulations on your Royal Highness's marriage.

Ever ready to rejoice at whatever affords a prospect of increased happiness to your Royal Highness, and a further security for the continued sway of a Royal House which has conferred on this realm so many benefits and blessings, we hail with especial interest and gratification the union of your Royal Highness with a daughter of an ancient nation, distinguished at all times for noble and generous qualities, and which holds a high place among the countries of Europe in literature and science; and above all, we regard it as an unspeakable boon that the Royal Lady whom we now welcome to our shores is endowed with all those virtues and attractions which are best calculated to bless and adorn domestic life, to assist in cheering the widowed solitude of our beloved Sovereign, and to sustain in unsullied lustre the honour and dignity of the British Court.

We earnestly hope and pray that this auspicious alliance may be productive of all the happiness with which we desire to see it attended.

The following Gentlemen were elected Fellows of the Society:—

Charles Cowan, Esq.
John Alexander Smith, M.D.

The following Donations to the Library were announced:—

Proceedings of the Royal Geographical Society of London. Vol. VII. No. 2. 8vo.—*From the Society.*

Quarterly Report of the Meteorological Society of Scotland, for the quarter ending 31st December 1862. 8vo.—*From the Society.*

Monthly Notices of the Royal Astronomical Society. Vol. XXIII. No. 5. 8vo.—*From the Society.*

Notice sur la vie et les travaux de P. L. A. Cordier, Membre de l'Institut, &c. &c. 8vo.—*From the Author.*

Proceedings of the Royal Horticultural Society. April. 8vo.—*From the Society.*

Monthly Return of the Births, Deaths, and Marriages, registered in the Eight Principal Towns of Scotland. March. 8vo.—*From the Registrar-General.*

Journal of the Chemical Society. April. 8vo.—*From the Society.*

Proceedings of the British Meteorological Society. Vol. I. No. 5. 8vo.—*From the Society.*

Die Fortschritte der Physik im Jahre 1860. XVI. Jahrgang. I. und II. Abtheilung. 8vo.—*From the Physical Society of Berlin.*

Memoirs of the Geological Survey of India. II. 3. 4to.—*From Dr Thomas Oldham.*

The American Journal of Science and Arts. Vol. XXXV. No. 104. 8vo.—*From the Conductors.*

Atti dell' Imp. Reg. Istituto Veneto di Scienze, Lettere ed Arti dal Novembre 1861 all' Ottobre 1862. Tomo VII., serie iii., dispensa 4–10; e tomo VIII., serie iii., dispensa 1-3. 8vo. —*From the Institute.*

Bulletin de la Société de Géographie, cinquième série. Tome IV. 8vo.—*From the Society.*

On the Forces concerned in producing Magnetic Disturbances (Proceedings of the Royal Institution of Great Britain). Balfour Stewart, Esq., F.R.S. 8vo.—*From the Author.*

Catalogue of the Minerals containing Cerium. By Dr William Sharswood. 8vo.—*From the Author.*

Description of a New Genus (Trypanostoma) of the family Melanidæ, and of forty-five New Species, &c. By Isaac Lea, LL.D. 8vo.—*From the Author.*

Proceedings of the Academy of Natural Sciences of Philadelphia. Nos. VII.-XII. 8vo.—*From the Society.*

Journal of the Academy of Natural Sciences of Philadelphia. New Series. Vol. V., Part 3. 4to.—*From the Academy.*

Mémoires de l'Académie des Sciences de l'Institut Imperial de France. Tome XXXIII. 4to.—*From the Academy.*

Cercles Chromatiques de M. E. Chevreul. 4to.—*From the Author.*

On the Law of Expansion of Superheated Steam. By W. Fairbairn, LL.D., and Thomas Tate, Esq. 4to.—*From the Authors.*

Bakerian Lecture. Experimental Researches to determine the Density of Steam at Different Temperatures, and to determine the Law of Superheated Steam. By William Fairbairn, Esq., LL.D., and Thomas Tate, Esq. 4to.—*From the Authors.*

Biblical Natural Science, being the Explanation of all References in Holy Scripture to Geology, Botany, Zoology, and Physical Geography. By the Rev. John Duns, F.R.S.E. Parts 1 to 4. 8vo.—*From the Author.*

Monday, 20th April 1863.

PROCEEDINGS

OF THE

ROYAL SOCIETY OF EDINBURGH.

SESSION 1863–64.

CONTENTS.

Monday, 7th December 1863.

[*For continuation of Contents, see pp.* 3 *and* 4 *of Cover.*